Accelerometric testing of selected points of the human locomotor system

Badania akcelerometryczne wybranych punktów układu ruchu

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Key words
gait, shock absorption, accelerometry

Abstract
Aim: The purpose of the paper was to determine changes in acceleration of the body parts while walking.
Material and methods: A tri-axial accelerometric sensor which was fastened to the foot, shank, knee, thigh, hip, L3 and L7 spinous process or the head of the person who took part in the test was used. Eleven healthy adults aged 18-24 participated in the test. Test participants were asked to walk 20 meters at their chosen, normal speed. The results were recorded on a computer at the time of the test.
Results: Tests results show that the higher the body part, the lower the amplitude of accelerations. The highest acceleration values for almost all test participants were observed at the heel level. Acceleration values gradually decreased in higher parts, though it must be noted that the results varied with regard to individual participants. As it was supposed prior to the test, in half of the participants the lowest values were the ones measured at the head level, while the other half showed lowest values in C7 spinous process. It turned out that the highest absorption rate of transient impulsive forces was in the ankle, which is considered to be the consequence of a special anatomical structure and the eversion mechanism during walking. The tests also confirmed the lack of symmetry between the right and the left side of the body.

Słowa kluczowe
chód, absorpcja wstrząsów, akcelerometria

Streszczenie
Cel: Celem niniejszej pracy było określenie zmian przyspieszeń na różnych poziomach ciała podczas chodu.
Materiał i metody: W badaniu wykorzystano trzyosiowy czujnik akcelerometryczny, który był mocowany do stóp, podudzi, kolan, ud, bioder, na wyrostkach kolczystych L3 i C7 oraz na czubku głowy badanych. W teście wzięło udział 11 zdrowych osób w wieku 18-24 lat. Badani mieli do przejścia 20 metrów z wybraną przez siebie, naturalną prędkością. Wyniki były zapisywane przez komputer w czasie rzeczywistym.
Wyniki: Badanie potwierdziło zmniejszanie się amplitudy przyspieszeń w miarę wzrostu poziomu ciała. U prawie wszystkich badanych najwyższe wartości przyśpieszenia zaobserwowano na piętach. Na wyższych poziomach przyspieszenia stopniowo malały, choć wyniki były zróżnicowane indywidualnie. U połowy badanych najmniejsze wartości zostały zarejestrowane na głowie, u pozostałych na wyrostku kolczystym C7. Najwyższy procentowo stopień absorpcji drgań miał miejsce w stawie skokowym i stopie, co przypisuje się specjalnej budowie tego stawu i mechanizmowi ewersji podczas chodu. Badania potwierdziły brak symetrii między prawą i lewą stroną ciała.

INTRODUCTION

Correct gait requires the correct construction and functioning of the skeletal and muscular system as well as the exertion of constant control over the said on the part of the nervous system. Many diseases and injuries are responsible for disturbances in the correct model of walking [1]. Pathological models of gait result in it being highly ineffective and the input of increasing amounts of energy[2].

The individual division on this paper was as follows: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search; G – grant and funding acquisition

Article received 16.07.2010; accepted: 23.08.2010

There exist many methods for the evaluation of gait. These methods differ from each other in, among other things, the way information is assembled and evaluated, the cost of the research itself, limitation in relation to the place it is conducted. We shall distinguish the techniques from a visual analysis of gait through technologically advanced visual and sensory systems enabling the identification of composite parameters of gait. Many reports confirm that within the evaluation of the motor system accelerometric variables appear to play a significant role[3,4].

The aim of the current work is:

1. To determine the parameters of acceleration for selected points in the motor system in healthy individuals;
2. The comparison of these values for the left and right sides of the body;
3. Testing at which levels of the body there appear the greatest dissipation in transient impulse force energy.

MATERIALS AND METHODS

The testing encompassed a group comprising 11 healthy individuals aged from 18 to 24. The average age of the male participants was 21.3 years while for the women it was 20.3.

Measurements were conducted by means of a sensor of acceleration of the ADXL type carried out using MEMS technology[5]. This enables the measurement of acceleration in three perpendicular axes up to do $\pm 30 m/s^2$ in a range of from 0 Hz to 3 kHz. The sensor was attached to a system for the acquisition of data with the use of a measurement card of the NI DAQ9007. Data acquisition was undertaken by a specialised program in which the tested frequency was set at 50 Hz, while the measurement range was $\pm 25 m/s^2$. The program in on-line mode carried out the measurement, filtration as well as the signal integration. The results of the measurements in the form of a trajectory of phases for three axes were projected onto a screen, while the signal was recorded to the file before filtration.

The program used an indicator of inclination (bending), graphs of the course of measured signals, the results of signal integration (velocity, acceleration, relocation) as well as phase graphs for the individual axes of the sensor[6].

The sensor was placed in turn on: the top of the head, the C7 spinous process, the L3 spinous process, both trochanter majors, mid thigh, on the side of the knees, mid shank and on both heels (Table 1). Following the application of the sensor the testees were to cover a distance of 20 metres at a natural speed chosen by themselves without footwear. The device registered the changes in acceleration and instantly sent them to the computer, which carried out their registration.

RESULTS

The initial data from the three-axis accelerometer is recorded by the computer in actual time to a text file (e.g. "pomiar02a.txt"). The number in the title of the file represents the number of the subsequent testee. The letter represents the subsequent points on the body where measurements have been taken (Table 1). Next with the help of a spreadsheet the minimal and maximum values for the axes X, Y, Z were found and the resultant for each of the earlier mentioned points of the body for all

Table 1

Anatomic localisation of measurement points

Anatomic localisation of measurement points		
a – top of the head	f – half the length of the left thigh	k – right shank
b – C7 spinous process	g – half the length of the right thigh	l – left heel
c –L3 spinous process	h – right knee	m – right heel
d – trochanter of the right thigh bone	i – left knee	
e – trochanter of the left thigh bone	j – left shank	

Table 2

Values of resultant acceleration amplitudes

No.	Head	C7	L3	Hip		Thigh		Knee		Shank		Heel	
				Right	Lewe	Right	Lewe	Right	Lewe	Right	Lewe	Right	Lewe
1	0,742	0,616	0,898	1,197	1,667	2,579	2,193	2,157	1,437	2,141	2,903	4,362	3,029
2	1,022	0,578	1,231	1,523	1,264	1,935	2,098	1,912	1,343	3,160	2,133	3,625	3,095
3	0,828	0,569	0,845	1,218	1,048	2,346	2,100	2,194	1,292	2,740	2,157	3,359	4,005
4	0,878	0,824	1,161	1,401	1,888	2,589	1,792	2,185	1,411	2,593	2,337	3,745	2,996
5	0,892	0,565	0,803	1,353	1,280	2,100	1,111	1,706	0,922	2,148	1,733	3,087	3,002
6	0,605	0,934	0,764	1,131	1,137	1,670	1,287	2,099	1,073	2,987	2,461	3,539	3,258
7	0,702	0,738	1,126	1,496	1,984	1,903	2,068	3,250	3,292	3,297	2,588	3,125	3,836
8	0,884	0,726	1,279	1,811	2,197	2,688	2,503	3,475	1,960	3,619	4,584	4,024	2,721
9	0,677	0,812	0,967	1,339	1,676	1,475	1,475	2,425	1,458	2,805	2,228	3,124	4,359
10	0,752	0,726	0,928	1,289	1,558	2,614	1,569	2,210	1,304	3,293	1,738	3,440	4,592
11	0,854	0,734	1,171	1,802	1,755	2,906	1,546	2,818	1,395	3,548	2,261	3,299	3,830

The minimal values in each of the tested individuals are coloured in green while the maximum values appear in red

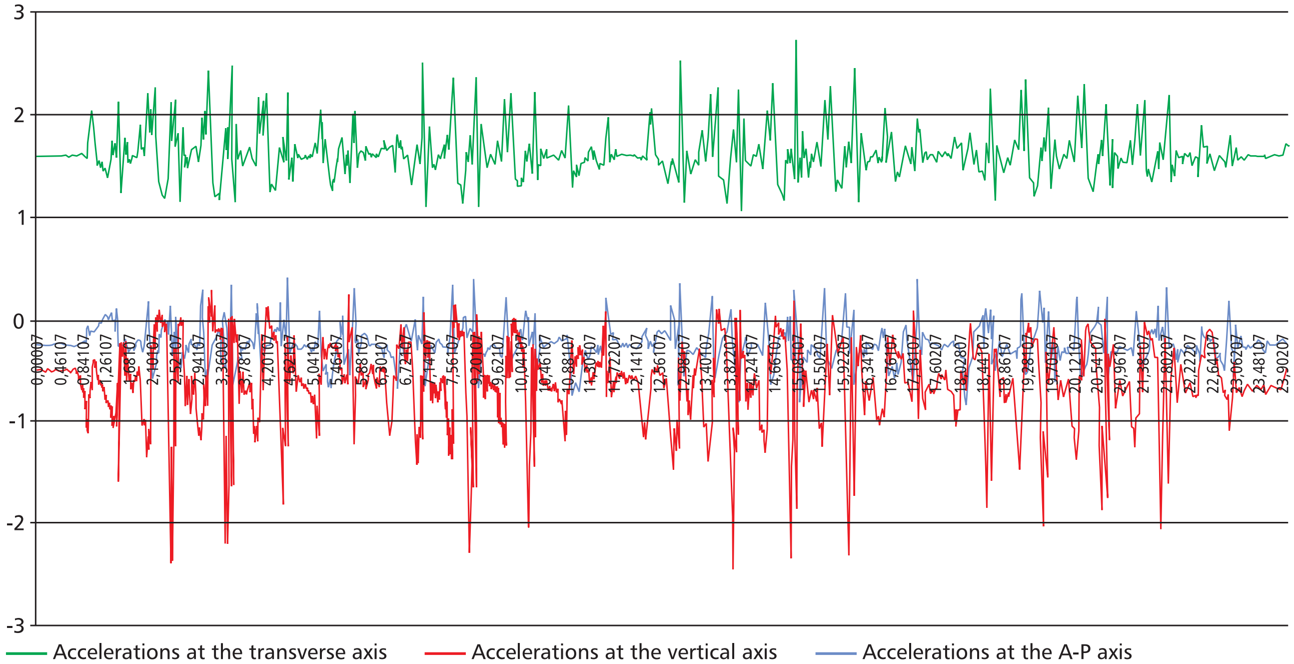

Figure 1
Graph of acceleration at three axes

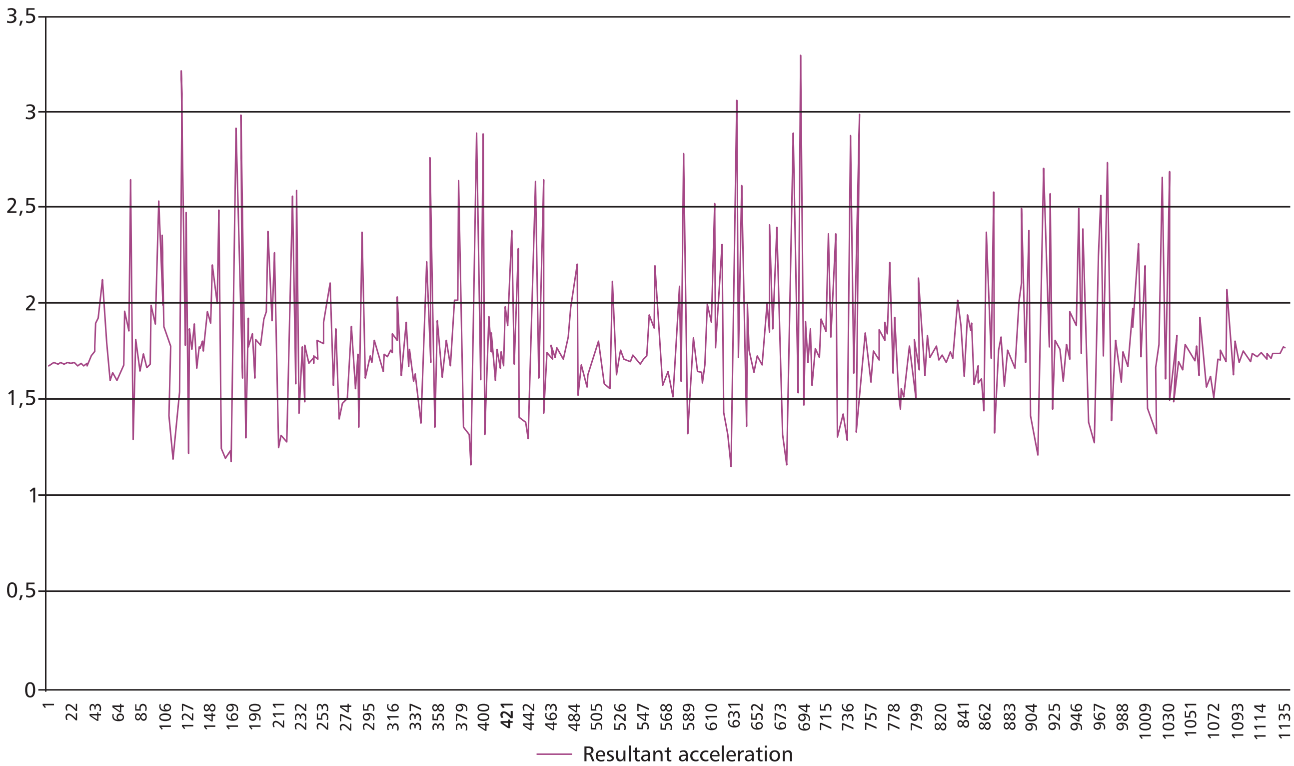

Figure 2
Values of the resultant vector of acceleration

those tested. The differences between these values were termed the maximum amplitude of transient impulse forces.

The amplitudes of acceleration (the differences between the maximum and minimum values) in the resultant axis for all patients are presented in table 2.

Table 2 shows that the amplitudes of acceleration clearly increase as a result of the lowering of the measurement point on the body. The minimal values in each of the tested individuals are coloured in green while the maximum values appear in red. One may notice that for all the individuals the least change in accelerations took place at the top of the head or at the C7 spinous process. The greatest amplitudes for all, with the exception of

Table 3

Absorption of transient impulse forces between selected body segments

No	The percentage of absorbed transient impulse forces between selected points of the body					
	head/ right hip	**head/ left hip**	**Right hip/ Right heel**	**Left hip/ left heel**	**head/ right heel**	**head/ left heel**
1	38,01	55,48	72,55	44,96	82,98	75,49
2	32,87	19,09	57,99	59,17	71,80	66,96
3	32,03	20,95	63,73	73,85	75,35	79,32
4	37,32	53,49	62,59	36,99	76,55	70,69
5	34,08	30,33	56,17	57,36	71,11	70,29
6	46,52	46,82	68,05	65,09	82,91	81,44
7	53,03	64,59	52,15	48,28	77,53	81,69
8	51,17	59,75	55,00	19,28	78,03	67,51
9	49,47	59,62	57,13	61,55	78,33	84,47
10	41,63	51,70	62,53	66,08	78,13	83,62
11	52,62	51,35	45,39	54,18	74,12	77,71

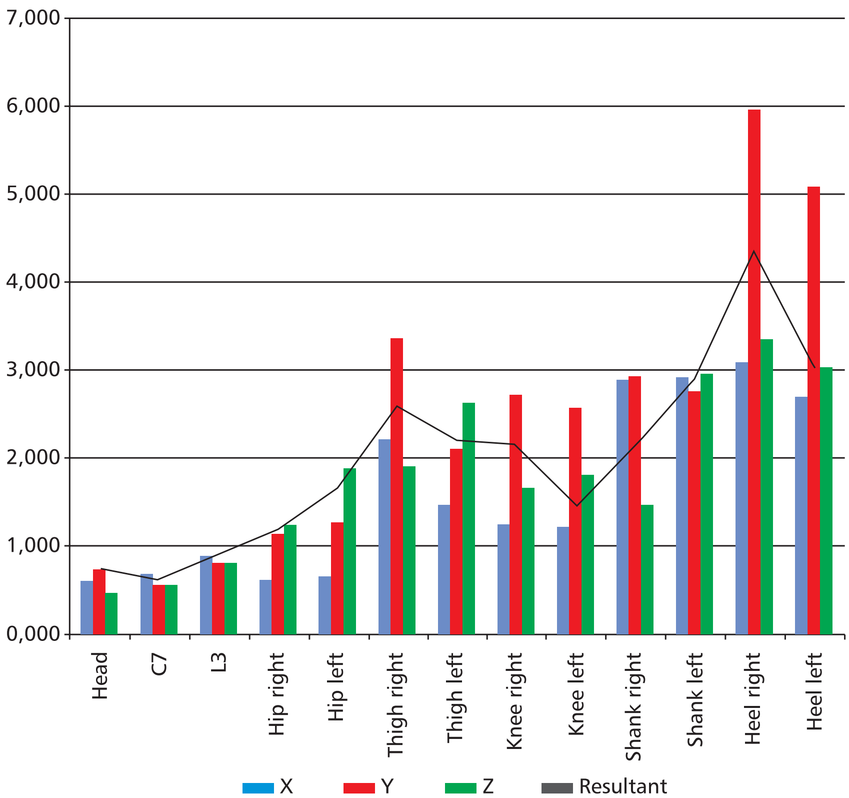

Figure 3
Amplitudes of acceleration at various levels of the body in a sample patient

one testee, appeared on the foot (only for the individual with number 8 did the maximum value appear on the left shank).

Even in such a simple analysis of data (Table 2) can asymmetry be observed, asymmetry that is based on the appearance of greater accelerations on the side of one of the ankles (for six patients this was the right ankle, while for the remainder the left). This is significant for it is from the heel that all transient impulse forces start to be derived.

We should therefore theoretically observe a permanent reduction in amplitude together with the height of the point of measurement. In practice, however, the line that represents this on the graph (Figure 3) displays a break (dip). Even by separating the right and left sides of the body we can see that, for example, for patient no. 1 the initial amplitudes on the left thigh are greater than on the same-sided knee. What is more interesting is that the higher values on the thigh than on the knee occur in seven of the eleven tested. However, the general tendency of an increase in the curve for increasingly lower levels of the body were borne out in all tested.

Making use of the equation 100% - $(a_{\text{r.f.}} - a_{\text{hd}}) \cdot 100\%$, where a_{hd} represents the amplitude of acceleration on the head, and $a_{r.f.}$ the amplitude of acceleration on the right foot, we are able to calculate what percentage of transient impulse forces was absorbed on the section from the right foot to the head. A similar value can be also calculated between the head and the left foot, the head and the right and left hip, as well as the same-sided hip and foot. The recorded values are presented in Table 3.

On the basis of the data in table 3 it can be seen that on the section between the head and the foot around 70 to 80% of the transient impulse force is absorbed. This has an undoubtedly sizeable significance for the protection of the Central Nervous System. There can also be noted asymmetry in the degree of absorption of these transient impulse forces. In comparing the route of impact from the right heel to the head with its route from the left heel to the head we can see that the greater value of absorption appears on the right side in 6 of those tested while on the left side in 5 testees. These changes are presented by figure 4.

In Table 3 is presented the percentage of transient impulse forces absorbed between selected points on the body. Let us take that $a_{head/right\ hip}$ represented the percentage value of transient impulse forces absorbed on the section from the right hip to the head, $a_{head/left\ hip}$ from the left hip to the head, while $a_{right\ hip/\ right\ heel}$, $a_{left\ hip/left\ heel}$, $a_{head/right\ heel}$ and $a_{head/left\ heel}$ represented the relevant percentage values of transient impulse forces absorbed on the section from the right heel to the right hip, the left heel to left hip, the right heel to the head and the left heel to the

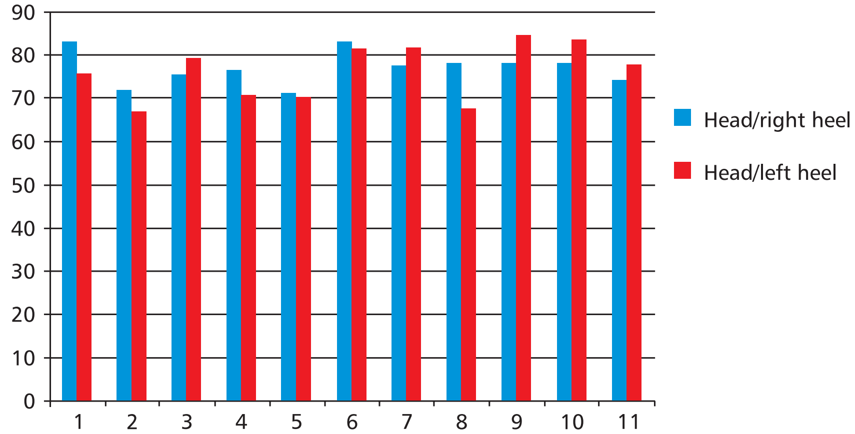

Figure 4
Differences in the absorption of shocks on the right and left side of the body

Table 4

Percentage differences in the absorption of shocks between the left and right side

No.	Difference between the route from: right hip to head, and left hip to head ($a_{head/right\ hip} - a_{head/left\ hip}$)	right heel to right hip, and left heel to left hip ($a_{right\ hip./right\ heel.} - a_{left\ hip./left\ heel.}$)	right heel to head, and left heel to head ($a_{head/right\ hip.} - a_{head/left\ hip.}$)
1	-17,47	**27,59**	**7,49**
2	**13,78**	-1,18	**4,84**
3	**11,08**	-10,12	-3,97
4	-16,17	**25,6**	**5,86**
5	**3,75**	-1,19	**0,82**
6	-0,3	**2,96**	**1,47**
7	-11,56	**3,87**	-4,16
8	-8,58	**35,72**	**10,52**
9	-10,15	-4,42	-6,14
10	-10,07	-3,55	-5,49
11	**1,27**	-8,79	-3,59

In Table the values for the calculated increased value of absorption on the right side in relation to the left are in bold (posi-tive values).

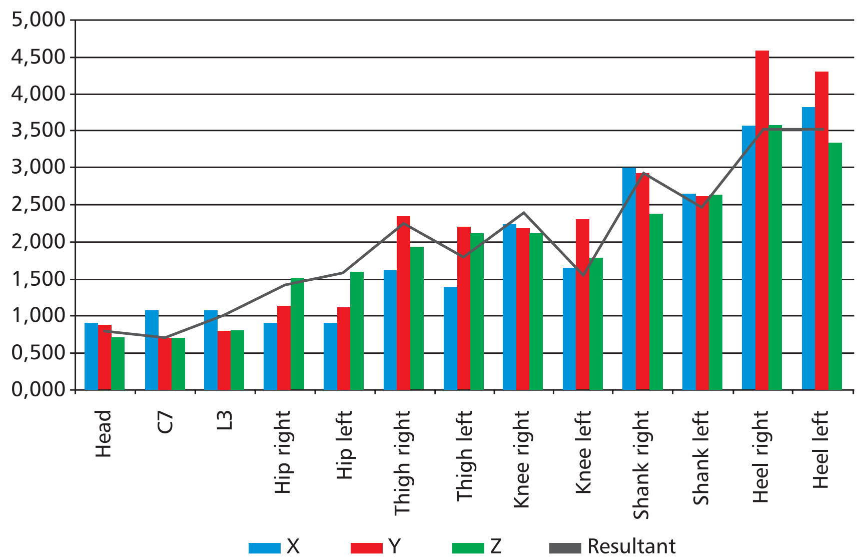

Figure 5
Mean amplitudes for all those tested

head. If we are to now undertake the following calculation: $a_{head/right\ hip}$ - $a_{head/left\ hip}$, we arrive at a result that is the percentage difference in the impacts between the left side and the right. A positive value means that in the given case greater values have been registered on the right side, while a negative value – on the left side. The above calculation is illustrated by table 4.

In Table 4 the values for the calculated increased value of absorption on the right side in relation to the left are in bold (positive values). This means of analysis of data received allows one to notice that on the route from the heels to the head the difference in the percentage of absorption of impacts between the right and left side is relatively low (maximum 10.5%). While taking into consideration the route from the heel to the hip, the difference is in the order of even 35.7%. This means that the percentage difference (between the route from the heel to the head and from the heel to the hip) must equal the section from the hip to the head.

Through the averaging of the values of amplitude for all those tested we obtain a graph (Figure 6). The high red columns on the heels draw attention on this graph. They constitute the values of the vectors of acceleration directed vertically upwards. In a half of those tested they are noticeably higher than the accelerations accompanying them on the X and Z axes (from 20-40% increased value); for 4 of those tested the values are similar, while for three only the foot displays much higher values Y. On figure 6 there are presented several of the most characteristic examples. In observing the graphs presented in figure 6 one can clearly see the lack of symmetry between the left and right side of the body. This is more clearly presented following the transformation of the graph into the form presented in figure 7, as well as the recording of the data in Table 5, in which mathematic symbols have been given that give on which side the amplitudes of acceleration are the greater.

It results from Table 5 that in the majority of cases amplitudes were greater on the right side 37 times, in relation to 17 times on the left side

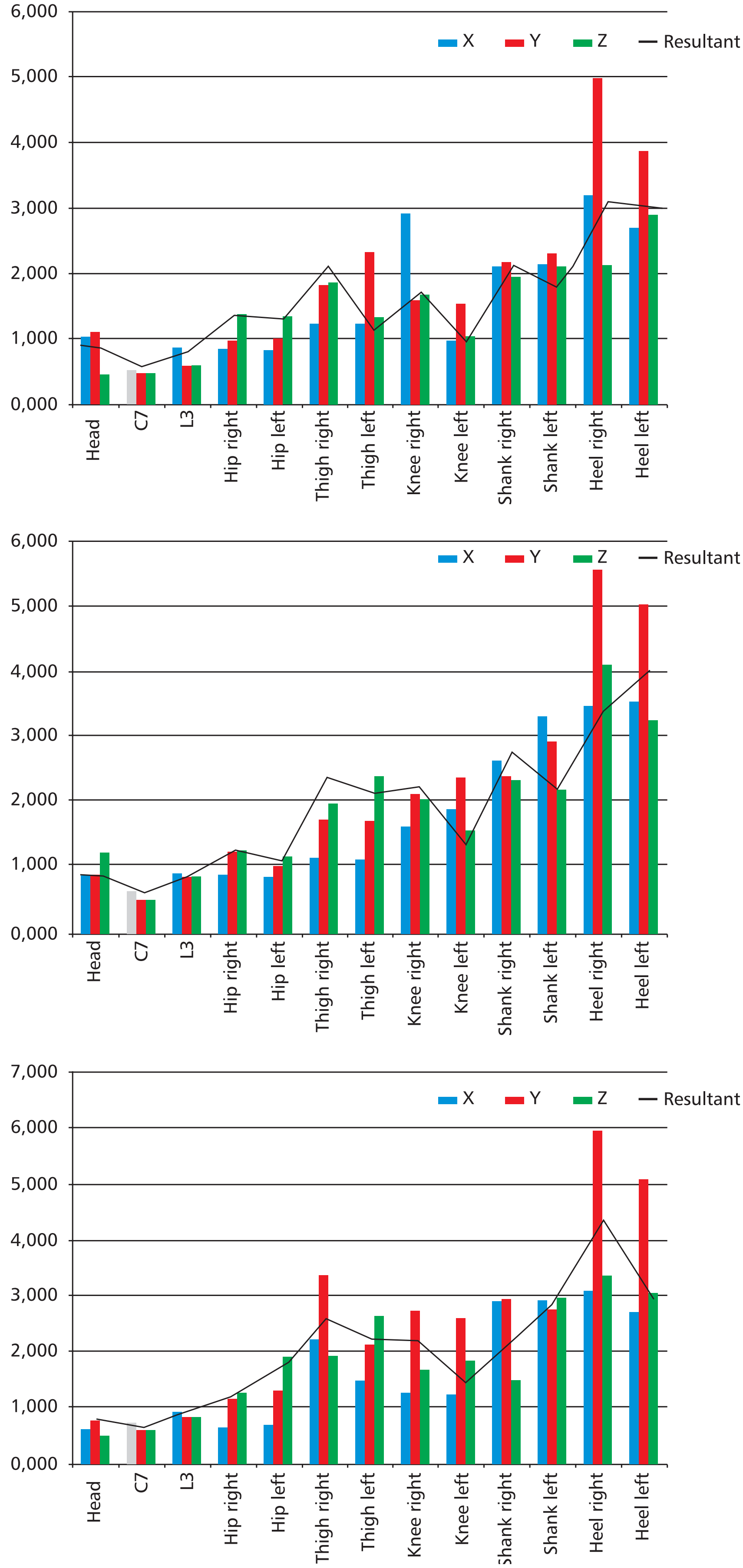

Figure 6
High amplitudes of acceleration in the Y axis in three sample patients

and a single case where they were similar. In the knee joint the left side had higher values in only a single case. At the height of the heel, amplitudes arrange themselves more or less evenly (6:5); while in the hip as the only joint, there dominates greater left-sided amplitudes – 7 out of 11 of those tested displayed such a tendency.

On the basis of the data assembled in the present work we are able to trace how the transient impulse forces are absorbed at the level of the joints of the lower limb and spine. The results presenting the values for the Y axis are correlated in Table 6 depicted in figure 8.

The negative values mean that the impacts were reduced with transfer to a higher body level. As one can see they are much greater than the positive values, which points to an increase in the transient impulse forces in transfer through the joint. The biggest columns below zero appear in the foot. This suggests the greatest absorption work is done by the feet themselves.

The graph presented in figure 9 illustrates the huge difference between the absorption of shocks in the ankle joint and the hip. It follows, however, to note that a lower value of impacts reach the hip. There is no doubt however that it is the foot that absorbs the greatest energy of the interaction.

It is also worth drawing attention to the fact that despite the appearance within a large part of the cases of higher values for the amplitude of acceleration in the head, in comparison to the C7 spinous process, in 10 out of the 11 cases the amplitudes in the head are less than those measured at L3. This consequently confirms the role of the spine in the damping of impacts.

On the graph depicted in figure 10 there are confronted the magnitude of transient impulse force absorption at various levels for all of those tested. One may clearly see that a large degree of asymmetry appears between the right and left sides of the body.

DISCUSSION

Accelerometric measurements are considered to be a reliable source for research into gait.[7,8,9]. The ease with

Table 5

Asymmetries of accelerations for the right and left lower limb

No.	Hip			Thigh			Knee			Shank			Heel		
1.	Rt	<	L.	Rt	>	L.	Rt	>	L.	Rt	<	L.	Rt	>	L.
2.	Rt	>	L.	Rt	<	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.
3.	Rt	>	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.	Rt	<	L.
4.	Rt	<	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.
5.	Rt	>	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.
6.	Rt	<	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.
7.	Rt	<	L.	Rt	<	L.	Rt	<	L.	Rt	>	L.	Rt	<	L.
8.	Rt	<	L.	Rt	>	L.	Rt	>	L.	Rt	<	L.	Rt	>	L.
9.	Rt	<	L.	Rt	=	L.	Rt	>	L.	Rt	>	L.	Rt	<	L.
10.	Rt	<	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.	Rt	<	L.
11.	Rt	>	L.	Rt	>	L.	Rt	>	L.	Rt	>	L.	Rt	<	L.

Rt. – right; L. - left

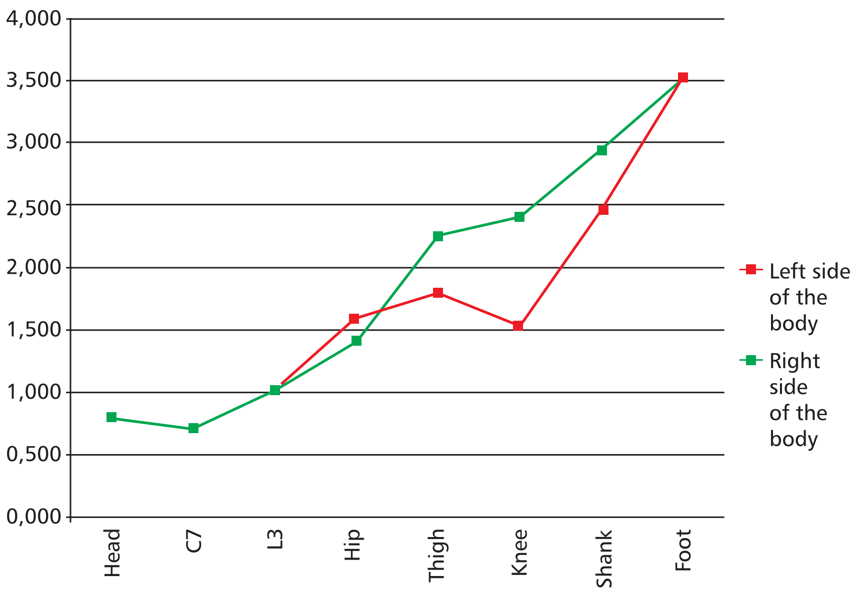

Figure 7

Asymmetries of accelerations for the right and left side of the body in a sample patient

which these measurements can be conducted, the small costs involved as well as the accessibility of these devices make for this being a valuable and useful research tool[10,11]. The potential measurement inaccuracies in the present work may be accredited to the effect of a number of factors. The first was the lack of possibilities for an ideal mapping out of the accelerations of selected points of the body, resulting from the means by which the detector of the accelerator metre was mounted. The most exact mounting would have been its location directly on the bode. Such a method is, however, extremely invasive. As a result the detectors were attached to the body by means of straps. As a result the accelerator metres were separated from hard tissue by soft tissue, which absorbed a part of the transient impulse forces. Such a means of binding is adopted in the relevant literature. In the tests conducted this factor was minimised dramatically as a result of the small weight of the detector used.

Another factor was the absence of the possibility to interpret the values of acceleration in all the points of the body during the self same test. As a result of the technical limitations which were the possibility of using only a single detector, those tested had to cover the set section as many times as there were highlighted points on the body. The tests described in the relevant literature have, however, confirmed the high repeatability of tests with the use of accelerometers attached to the skin[7,8,12,13]. Despite the fact that these changes should not have a significant effect on the result of the tests it is not, however, with complete certainty possible to state that they were not a cause of the emergence of minor artefacts.

The absorption of the shocks that arose during gait has been the subject of a series of tests. Ratcliff and Holt[14] in their work measured the amplitude of the transient impulse forces arising in the foot, which reaches the head. Patients were observed as they moved along a running machine at various speeds. It was claimed that between 8 to 15% of the shock amplitude generated in the foot reached the head.[14] That these forces may have a significant negative effect on health can be borne out by the research conducted by Chen et al.[15] They decided to test the hypnosis that stated that the difference in the frequency of joint degeneration in Chinese women as well as white women is connected with the style of walking. In the Chinese population the index of the appearance of degeneration is significantly lower than in the white population. 117 healthy women were tested, who were to cover a distance of 8 metres. With the help of a computer optoelectronic system, the parameters were measured, such as: the natural gait speed, the length of stride, the steadiness and maximum burden during the contact of the heel with the floor. It turned

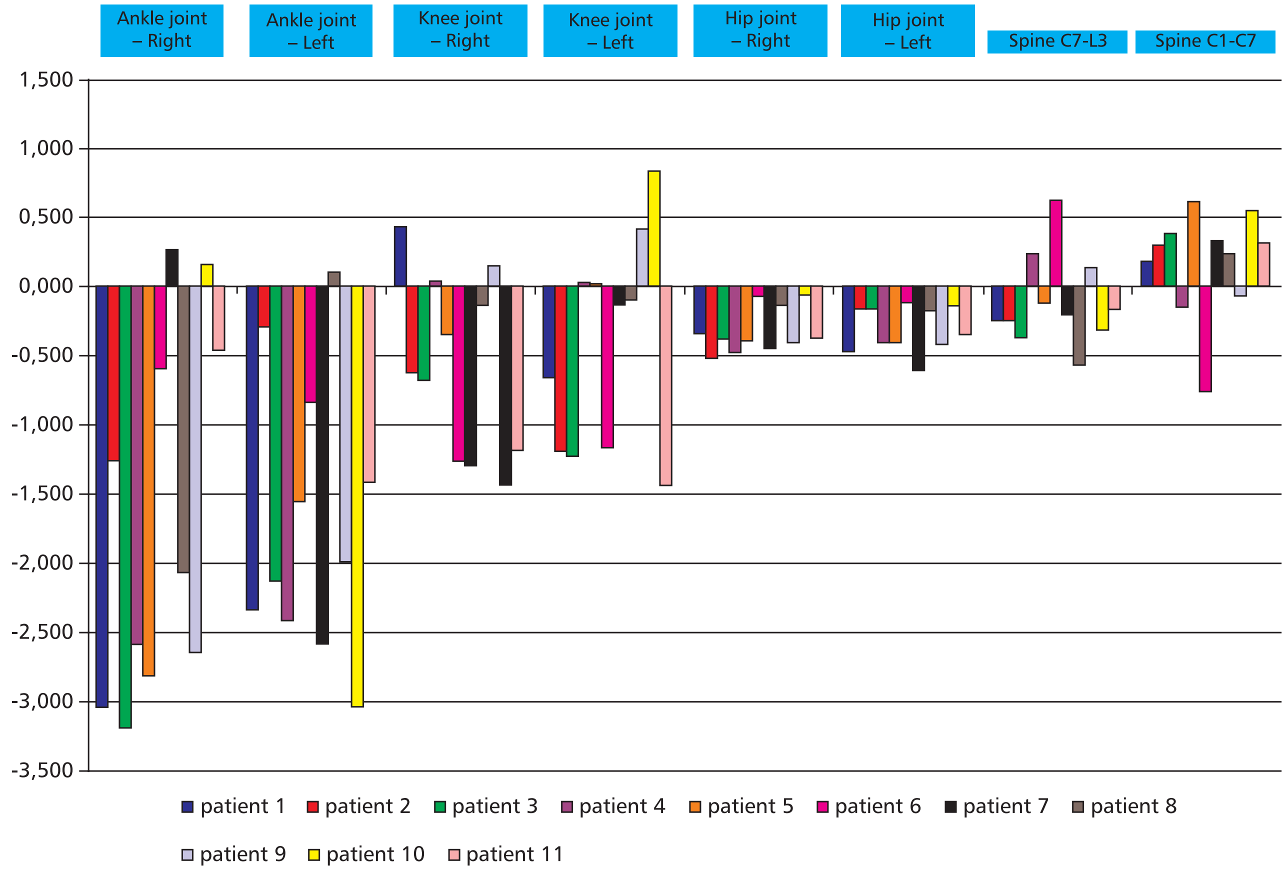

Figure 8
Absorption of shocks in the Y axis in the joints of the lower limb and spine

Table 6

Absorption of shocks in the Y axis in the lower limb joints and the spine

No.	Ankle joints		Knee joints		Hip joints, sacrovertebral, sacro-iliac, spinous process below L3		Spine	
	Right	Left	Right	Left	Right	Left	C7-L3	C1-C7
1.	-3,032	-2,322	0,431	-0,652	-0,344	-0,464	-0,247	0,183
2.	-1,249	-0,285	-0,617	-1,185	-0,510	-0,160	-0,243	0,301
3.	-3,180	-2,128	-0,682	-1,228	-0,384	-0,164	-0,366	0,390
4.	-2,575	-2,407	0,043	0,035	-0,466	-0,406	0,240	-0,142
5.	-2,813	-1,552	-0,344	0,010	-0,390	-0,408	-0,119	0,618
6.	-0,589	-0,836	-1,255	-1,166	-0,073	-0,111	0,621	-0,759
7.	0,268	-2,571	-1,292	-0,130	-0,442	-0,602	-0,199	0,336
8.	-2,060	0,105	-0,127	-0,088	-0,130	-0,172	-0,564	0,237
9.	-2,640	-1,983	0,151	0,422	-0,408	-0,410	0,134	-0,071
10.	0,159	-3,024	-1,430	0,832	-0,060	-0,136	-0,307	0,548
11.	-0,457	-1,408	-1,183	-1,430	-0,366	-0,342	-0,160	0,319

out that white women walked decidedly quicker and decidedly more powerfully struck their heel against the floor than did the Chinese.[15]

In the course of correct gait the dynamic interaction at the point of contact of the foot with the floor as well as the mechanical interaction of the muscles should be dampened and dissipated in such a way that to the upper part of the organism, particularly the head, there reaches the least energy of the kinetic interaction. The results obtained in these tests suggest that the transient impulse forces that arise during walking are absorbed to the greatest degree by the foot. This fact is hardly surprising for it is the foot that possesses both arches and a mechanism of eversion having a key significance in the dampening of transient impulse forces. In the tests presented the measurements were conducted without shoes for the period of walking. However, the majority of authors carry out measurements while walking with footwear on. Ledoux[16] reports that the viscose

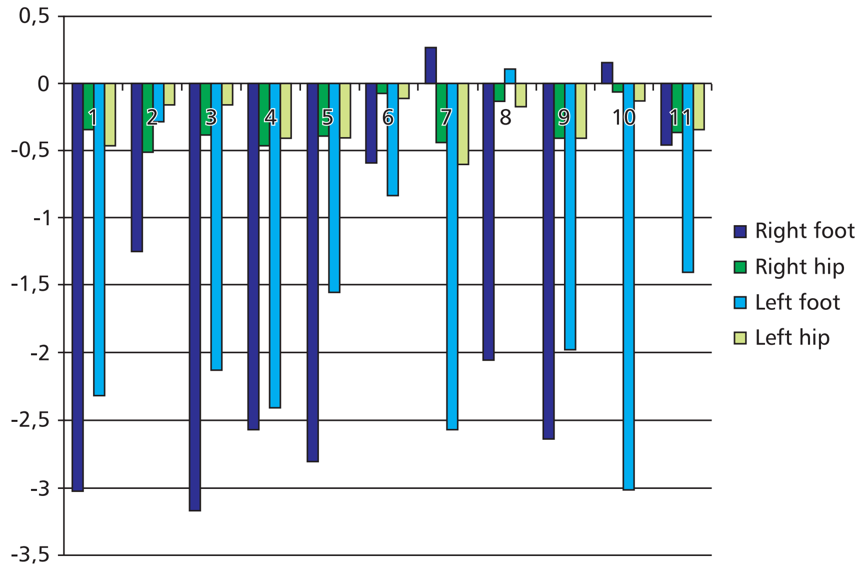

Figure 9

Differences between the absorption of shocks in the ankle and hip joint in 11 patients

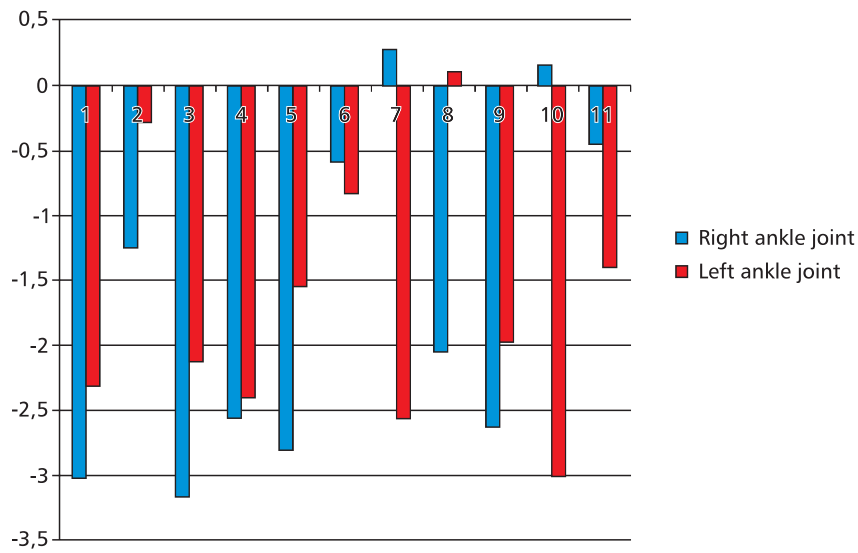

Figure 10

Absorption of transient impulse forces in patients' left and right ankle joint

elastic materials present in soles absorb in total around 44.5% of the impact that occurs during walking [16]. In turn the very plantar aponeurosis takes up 14% of the burden of the limb[17]. Equally Folman[18] has confirmed that the application within footwear of viscose-elastic inserts weakens the high-frequency of the impacts brought about by the reaction of the sole by about a third. According to him this is a significant difference having a sizeable significance for the preventive treatment of pain and damage to the spine brought about by walking[18]. The knee joint as opposed to the foot does not possess such specialised mechanisms for the absorption of impacts. Its large surface area, hinge construction as well as the presence of meniscuses allows for a reduction in the values of acceleration although not to such a degree as in the foot. We may observe similar results in the hip, where the changes although relatively small were for all the patients of a negative value which constitutes a reduction in the transient impulse forces that arise from the impact of the heel on the ground. It also follows to remember that with regard to the means of testing the 3rd and 4th column from the end of figure 10 represents the summary action of the hip joint, the sacroiliac as well as the joints of the spine from L3 downwards. The changes in acceleration for the section C7-L3 of the spine are no longer so clear-cut and point to increased individual differentiation. A similar situation is in the neck of the spine where the majority of those tested obtained positive values. Dissipation of energy is not the only method for the dampening of transient impulse forces. It is worth noting that in the course of walking there exists the possibility to accumulate a part of the energy with the aim of later utilization. A circular movement of the arms as well as the shoulders is an example of the transformation of progressive movement into rotatory movement. In utilising the inertial moment of the rotating part of the body the amount of energy supplied to the osteo-muscular system during walking is lowered. These mechanisms are used in various degree by people, from which can arise the differences that have appeared in the results obtained. The mass of the head, as a mass concentrated on an elastic flaccid connection as provided by the neck acts as a dynamic dampener. The regulation of its characteristic frequencies is regulated by the stiffness of the neck. Its activity is realised to a large degree in the horizontal plane. With the same it has a small influence on the amplitude of vertical acceleration.

The differences between the dominating and the non-dominating side of the body that were observed during the testing that constituted the basis of the current work are widely described in the relevant literature on the basis of other research. The main method with application in the comparison of structure and activity of the left and right upper and lower limb is EMG.

On the basis of research using this method it has been shown that, among other things, while standing the greater part of the body mass is maintained by the non-dominating limb. The dominating limb is found in preparedness for movement such as, for example, undertaking a step compensating for the deflexion of the centre of gravity. Observation of the trajectory of limb movement during gait has shown increased deflexion of the non-dominating side, confirming an increased exactness in the movements of the dominating side.[19]

The results obtained in the current tests for the differences between the right and left side of the body may result from the fact that in the majority of the population the right side of the body is dominant. Increased amplitudes of acceleration in the right foot may result from the greater muscle strength in this limb and therefore from the more energetic placing of the foot on the floor. For the more muscular and functional limb better dampens transient impulse forces than the weaker left. Hence the amplitudes in the left hip are on the whole greater than on the right side. Differences may also result from variable scopes in movement for the dominant and non-dominant limb[20]. In the description of asymmetry Bilodeau's research stands out, who by means of an accelerometer tested muscular trembling of burdened hands on both sides of the body. It appeared that the amplitudes of the transient impulse forces measured by the accelerometer in those tested were greater on the non-dominant side[21]. The lack of symmetry is even noticeable in the difference in the feeling of pain between the right and left side of the body. The testing of 131 healthy individuals showed that the pressure pain threshold for the dominant limb is significantly higher than for the non-dominant[22].

The research conducted confirms that the introduction of parameters of accelerometric evaluation for the description of gait significantly influences the comprehensive evaluation of phenomena accompanying man's locomotion.

CONCLUSIONS

The results of the tests conducted allowed the following conclusions to be drawn:

1. The values in the amplitude of acceleration clearly increase as a measure of the lowering of the measurement point on the body. Shocks arising as a result of the heel's impact on the ground are partially absorbed at increasingly higher measurement points. This tendency has been pointed to by all the researchers although this has not been as clear in all as might have been expected. For a half of those tested the higher values occurred on at the top of the head than at the C7 spinous process.
2. Research with the use of an accelerometer allows one to indicate asymmetry in the motion of the lower limbs. Only in the case of a few measurements were the differences of different limbs at the self same level not large. The vast majority of those tested displayed significant deviations between the values obtained for the right and left lower limb.
3. The foot absorbs the greatest energy of transient impulse forces. This is demonstrated by appearance in it of special mechanisms like the motion of eversion during the contact of the limb with the ground, the presence of arching as well as materials with viscous elastic characteristics in the sole of the foot. The assumed highest value of amplitude falling on the foot was found in the right foot of all those tested. However, despite the assumptions in almost a ¼ of those tested this was not the value of the Y vertical vector.

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Translated from the Polish by Guy Torr